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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Applicati n Number	10/008,998
Filing Date	December 4, 2001
First Named Inventor	Blohm, Werner
Group Art Unit	2877
Examiner Name	Richard A. Rosenberger
Attorney Docket Number	48619/265797

Total Number of Pages in This Submission: 25

ENCLOSURES *(check all that apply)*

- [x] Fee Transmittal Form
  - [x] Fee Attached
- [ ] Amendment / Response
  - [ ] After Final
  - [ ] Affidavits/declaration(s)
- [ ] Extension of Time Request
- [ ] Express Abandonment Request
- [ ] Information Disclosure Statement
- [ ] Certified Copy of Priority Document(s)
- [ ] Response to Missing Parts/ Incomplete Application
  - [ ] Response to Missing Parts under 37 CFR 1.52 or 1.53
- [ ] Assignment Papers *(for an Application)*
- [ ] Drawing(s)
- [ ] Licensing-related Papers
- [ ] Petition
- [ ] Petition to Convert to a Provisional Application
- [ ] Power of Attorney, Revocation Change of Correspondence Address
- [ ] Terminal Disclaimer
- [ ] Request for Refund
- [ ] CD, Number of CD(s) _____
- [ ] After Allowance Communication to Group
- [ ] Appeal Communication to Board of Appeals and Interferences
- [x] Appeal Communication to Group *(Appeal Notice, Brief, Reply Brief)*
- [ ] Proprietary Information
- [ ] Status Letter
- [x] Other Enclosure(s) *(please identify below)*:
  1. Appeal Brief, in triplicate, together with Exhibits A, B, C

Remarks

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SEP 23 2003
BOARD OF PATENT APPEALS AND INTERFERENCES

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm or Individual name	James L. Ewing, IV, Reg. 30,630 Kilpatrick Stockton LLP
Signature	James L Ewing
Date	9/16/03

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as certified first class mail in an envelope addressed to: Commissioner for Patents, P. O. Box 1450, Alexandria, Virginia 22313-1450

Typed or printed name	ANGELA M. ROSSI		
Signature	Angela M. Rossi	Date	9/16/03

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FEE TRANSMITTAL for FY 2003

Effective 01/01/2003. Patent fees are subject to annual revision.

☒ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 160

Complete if Known	
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METHOD OF PAYMENT (check all that apply)

☒ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☒ Deposit Account:

Deposit Account Number: 11-0855

Deposit Account Name: Kilpatrick Stockton LLP

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	750	2001	375	Utility filing fee	
1002	330	2002	165	Design filing fee	
1003	520	2003	260	Plant filing fee	
1004	750	2004	375	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 0

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20 ** =	0	X		=	0
Independent Claims		-3 ** =	0	X		=	0
Multiple Dependent				X		=	0

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	84	2201	42	Independent claims in excess of 3
1203	280	2203	140	Multiple dependent claim, if not paid
1204	84	2204	42	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0

***or number previously paid, if greater; For Reissues, see above*

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet.	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	410	2252	205	Extension for reply within second month	
1253	930	2253	465	Extension for reply within third month	
1254	1,450	2254	725	Extension for reply within fourth month	
1255	1,970	2255	985	Extension for reply within fifth month	
1401	320	2401	160	Notice of Appeal	
1402	320	2402	160	Filing a brief in support of an appeal	160
1403	280	2403	140	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive – unavoidable	
1453	1,300	2453	650	Petition to revive – unintentional	
1501	1,300	2501	650	Utility issue fee (or reissue)	
1502	470	2502	235	Design issue fee	
1503	630	2503	315	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17 (q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	750	2809	375	Filing a submission after final rejection (37 CFR § 1.129(a))	
1810	750	2810	375	For each additional invention to be examined (37 CFR § 1.129(b))	
1801	750	2801	375	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid SUBTOTAL (3) ($) 160

SUBMITTED BY		Complete *(if applicable)*			
Name (Print/Type)	James L. Ewing, IV	*Registration No. Attorney/Agent)*	30,630	*Telephone*	404.815.6494
Signature	James L Ewing IV			*Date*	9/16/03

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8th #11/Appeal Brief 12/18/03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In Re Application of:	Werner Blohm, Harald Sikora and Adrian Beining
Serial No. of Parent Application:	10/008,998
Filing date of Parent Application:	December 4, 2001
For:	METHOD OF MEASURING THE DIAMETER OF AN ELONGATED ARTICLE OF A CIRCULAR CROSS SECTION
Examiner:	Richard A. Rosenberger
Group Art Unit:	2877

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Commissioner of Patents
P. O. Box 1450
Alexandria, Virginia 22313-1450

Attorney Docket No. 48619/265797
Date:

APPELLANTS' APPEAL BRIEF

To the Honorable Board of Patent
Appeals and Interferences

Appellants submit, in triplicate, this Appeal Brief together with a check in the amount of $160.00 pursuant to 37 CFR 1.17(c).

(1) **Real Party In Interest**. Sikora Industrieelektronic GmBH, Bremen, Federal Republic of Germany.

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(2) **Related Appeals and Interferences**. None.

(3) **Status of Claims**. Pending are claims 25 - 80. All stand rejected as obvious under 35 USC § 103 (and on no other grounds). Previously pending claims 1 - 24 were cancelled before the first Examiner's Action in this application.

(4) **Status of Amendm_nts**. No amendments were submitted after any final Examiner's Action in this application.

(5) **Summary of Invention**. The invention relates to measuring a dimension of an article by illuminating a portion of the article with a beam of light that has a non-planar wavefront, receiving the light on an array, and analyzing signals relating to the intensity of the received light using Fresnel diffraction theory. The invention takes advantage of diffraction patterns from light that has a non-planar (or fan-shaped) wavefront. By contrast, the prior art Ring patent relied upon in the Examiner's Actions in this matter, taught that parallel light, light with a planar wavefront, is to be used for diffraction pattern analysis. The present invention thus reflects the discovery that diffraction pattern analysis can and should be done using light that is not parallel, to provide low cost, smaller and compact devices for measuring objects.

According to all claims at issue (all are process claims), information from the light sensing array is evaluated (1) according to Fresnel diffraction theory; (2) according to the assumption that the wavefront from the light source is nonplanar, and (3) by distancing the source, article and array such that the intensity pattern in the vicinity of one shadow edge cast by the article is at most negligably superimposed on the intensity pattern in the vicinity of the other or another shadow edge. Diffraction pattern analysis of non-planar wavefront light according to the present invention allows a point source of light to be used instead of arrays that generate and sense parallel light, so that processes

according to the invention can be carried out in devices which are affordable and can fit in the palm of the hand, yet serve as an accurate and reliable instrument for uses such as measuring objects.

(6) <u>Sole Issue</u>. The sole issue is whether the rejection of all pending claims as obvious under 35 U.S.C. § 103 is improper, when the references applied by the Examiner nowhere teach or suggest the substantive, meaningful and patentably distinct requirements and limitations that are found in the pending claims.

(7) <u>Grouping of Claims</u>. A copy of the two primary references applied by the Examiner are attached as Exhibits A and B. The claims can be considered to form four groups. All claims contain the limitations that information from the array is evaluated (1) according to Fresnel diffraction theory; (2) according to the assumption that the wavefront from the light source is nonplanar; and (3) by distancing the source, article and array such that the intensity pattern in the vicinity of one shadow edge cast by the article is at most negilgably superimposed on the intensity pattern in the vicinity of the other or another shadow edge. Additionally, each group contains additional limitations including the following:

Group I. Claims 25 - 42 (Independent 25 and dependent claims 26 - 42) form a first group of claims. Independent claim 25 requires that distances between the source, article and array are selected such that the intensity pattern in the vicinity of one shadow edge cast by the article on the array is at most

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negligibly superimposed on the intensity pattern in the vicinity of the other shadow edge cast by the article on the array.

Group II. Claims 43 - 48 (Independent 43 and dependents 44 - 48) form a second group of claims. Claim 43 adds the limitation that determination of the dimension of the article includes compensating for the difference between (i) the dimension of the article that casts the intensity pattern; and (ii) the diameter of the article.

Group III. Claims 49 - 62 (Independent 49 and dependents 50 - 62) form a third group of claims. Claim 29 adds the requirement of at least two sources and two sensors.

Group IV. Claims 63 - 80 (Independent 63 and dependents 64 - 80) form a fourth group of claims. Claim 63 adds the limitation that the signals from the sensors corresponding to light intensity are filtered in order to attenuate effects of dirt.

(8) <u>Argument</u>.

a. Summary of Argument.

The claims at issue (which are all process claims and which include four independent claims, 25, 43, 49 and 63) all address and define measuring a dimension of an article by illuminating a portion of the article with a beam of light in a way that, unlike the cited references, takes advantage of diffraction patterns from light assumed to have a non-planar (or fan-shaped) wavefront. According to all newly pending claims, signals corresponding to the diffraction patterns are

evaluated according to Fresnel diffraction theory, and according to the assumption that the wavefront from the light source is nonplanar, to determine the dimension. As discussed below and in the application at the places cited below, Appellants' resulting measuring processes can carried out in smaller, less expensive and less mechanically complex devices which reflect the invention's appreciation that the light does not have to be made parallel for diffraction analysis to occur, as the prior art Ring patent teaches. Instead, the light can eminate from a point source, even though that source creates a non-planar wavefront requires Fresnel diffraction analysis.

Furthermore, each of the four independent claims adds additional limitations to the invention. Independent claim 25 adds that distances between the source, article and array are selected such that the intensity pattern in the vicinity of one shadow edge cast by the article on the array is at most negligibly superimposed on the intensity pattern in the vicinity of the other shadow edge cast by the article on the array. Claim 43 adds that limitation and, among others, that determination of the dimension of the article includes compensating for the difference between (i) the dimension of the article that casts the intensity pattern; and (ii) the diameter of the article. Claim 49 requires at least two sources and two sensors. Claim 63 adds the limitation that signals from the sensors corresponding to light intensity in the intensity pattern in order to attenuate effects of dirt. (Cites to portions of the application which disclose these limitations are listed in Section 8C of this Document.)

As discussed below, the French reference (Exhibit A) (identified and discussed more fully in the next section) discloses measuring the distance between shadow edges cast by an article using the ***geometrical*** approach that treats light as a ray phenomenon, rather than analyzing diffraction patterns as in the present invention.

The other primary reference applied against the claims, the Ring patent, specifically and expressly considers the French reference's geometrical approach, considers it different, and rejects the geometrical approach. (Exhibit B) (identified and discussed more fully in the next section) Ring characterizes the French reference geometrical or ray approach as requiring a highly accurate, and thus not readily available, light sensor and that it relies too heavily on accurate spacing of the workpiece from the sensor. (Ring, column 1, lines 15 – 46) Ring solves this problem by teaching that the light must be made parallel, with a planar wavefront, in order to do the more accurate diffraction analysis. (Ring, column 3, lines 14 – 17; Figures 1, 6) Ring's departure from the geometrical or ray approach is reflected in a large and complex structure with multiple sensors and lenses to create and analyze diffraction patterns from ***parallel light***. (See, e.g., Ring Figure 6) Size and complexity may not matter, since the Ring system is shown to measure workpiece dimensions in connection with a lathe-type device. Ring only discloses evaluation of diffraction patterns formed by parallel light, or light having a planar wavefront, a simpler mathematical case than in Appellants' invention. Whether that is because Ring

was filed circa 1985 before processing power of the sort required by Appellants' invention was readily available, or because the Ring measurement device is disclosed as being used on a lathe-like device to measure apparently sizeable dimensions of a workpiece, what is clear is Ring does not teach or suggest the compact, reliable, accurate device made possible by Appellants' invention. It certainly does not do that in combination with the French rejection, whose non planar light approach it rejects and eschews.

In short, the Ring patent teaches in response to the French patent's geometrical approach for analyzing nonplanar wavefront light that the light must be made parallel for diffraction analysis to occur. It thus teaches away from the present invention, which recognizes that diffraction analysis can and should be done using non planar wavefront light. In any event, there is nothing in either Ring or the French reference that would teach, suggest or incentivize combination of them. Appellants accordingly below respectfully submit that there is not a prima facie obviousness case as required here, and they respectfully request such a position be reconsidered and withdrawn.

b. The References.

The two primary obviousness references that formed the basis for previous obviousness rejections were: (1) U.S. Patent No. 4,854,707 issued August 8, 1989 to *Ring et al* entitled "Method and Apparatus for the Optical Electronic Measurement of a Workpiece" ("Ring patent"); and French publication No. 2,371,673 published June 16, 1978 corresponding to French patent

application no. 76 35004 filed November 19, 1976 in the name of "Societe Industrielle De Liaisons Electriques - Silec (the "French reference").

1. French Reference

The French reference, as the most recent, May 15, 2003 Examiner's Action correctly recognizes, discloses measurement of the diameter of an article by placing it in a fan-shaped beam of light and determining where the edges of the resulting shadow are located relative to certain CCD or other detectors. (May 15, 2003 Examiner's Action, page 2, line 14 – page 3, line 11.) Though that Action characterizes the light source in the French reference as creating an intensity pattern, it nowhere points to any disclosure in the French reference which recognizes the existence or use of this aspect of the French reference light pattern or that any sort of analysis should be used other than a geometrical approach. Id. All the Examiner's Action expressly concedes is that the French reference does not teach use of the Fresnel sort of diffraction analysis. (May 15, 2003 Examiner's Action, page 3, lines 16 – 18.)

But, says the Action, it would be conventional (and thus unpatentable) to use diffraction pattern analysis in the French patent device, citing the Ring patent for that proposition. (May 15, 2003 Examiner's Action, page 3, line 18 – page 4, line 8.) The Action completely ignores and fails to mention that the Ring patent teaches that parallel light, rather than non planar wavefront light, is to be used for such diffraction pattern analysis. Id. This important omission occurs despite Appellants having made this showing repeatedly, in considerable length and

detail, and at significant expense during the prosecution of this patent application. (April 23, 2003 Response, page 3; July 11, 2002 Response, pages 4, 8 (see boldface language); 10 – 13; December 4, 2001 Preliminary Amendment, pages 19, 20 – 21, 22 – 26.) Beginning with the December 4, 2001 preliminary amendment, the appellants go to great length to show why the Ring parallel light diffraction pattern analysis is different from and departs in another direction from the present invention's use of Fresnel diffraction pattern analysis to measure an object illuminated with non-planar wavefront light. Id.

Thus, the primary issue in this matter could be characterized this way: Even though Ring teaches diffraction pattern analysis of parallel light, does that simply automatically sweep in the invention's significant recognition that diffraction analysis should be used for non-planar wavefront light, or that Fresnel diffraction analysis should be used for that purpose? Appellants think not.

2. The Ring Patent

As the May 15, 2003 Examiner's Action recognizes, the Ring patent discloses use of diffraction pattern analysis to measure an object. (May 15, 2003 Examiner's Action, page 3, lines 18 – 20.) However, despite appellants having repeatedly raised the issue, as mentioned above, the Action fails to address the fact that no drawing and no text of Ring discloses other than using a source of parallel light to create the diffraction pattern. At Ring, column 3, lines 15-17, by contrast, it is made clear that the radiation is directed parallel. Figures 1 and 6 of

Ring make that point distinctly. Figure 1 shows only parallel light rays. There is no drawing or text showing a non-parallel light case.

Ring figure 6 is consonant with the first sentence of the patent which says that the optical electronic method it discloses is for measuring a "work piece." Figure 6 shows a device resembling a lathe, and the light source 3, combined with lens system 7, is a sizeable structure occupying a considerable part of one side of a "sled 22." The sled, which carries the light sources 3 and the lens system 7, is discussed at column 4 lines 26-44. The sled rides on guide rails 21 so that light sensors, light sources and lens can be positioned as desired relative to the work piece. Id.

The Ring apparatus goes to considerable structural effort to illuminate the work piece with parallel light. Ring embraces structural complexity, with multiple lenses and sensors, to create the parallel light diffraction patterns in its quest to escape the geometrical or ray approach as taught in the French reference. For instance, Ring discusses the need to address aberration effects in the lenses (Ring, column 3, lines 18-21). In any event, Ring fails to disclose or suggest use of any other than a complex structure with multiple lenses and sensors for creating and analyzing a source of parallel light diffraction patterns.

c. Appellants' Invention.

Processes of the present invention do not categorically reject the geometrical or ray based approach of the French reference by resorting to parallel light to do diffraction pattern analysis as Ring does. Accordingly,

processes of the present invention are not forced to a embrace a large and structurally complex system that requires a number of lenses and sensors like Ring does. Instead, processes of the present invention recognize that diffraction pattern analysis can and should be done using non-parallel light (such as from a point source) to measure objects. Application page 3, lines 4-5; page 10, lines 11-16; page 10, lines 27-28; Figures 1, 4, 5, 6, 7, 9, 11, 12. Processes of the invention analyze the diffraction pattern using Fresnel diffraction theory, a theory that takes into account the non-planar wave front from the point source. Application page 3, line 18 -- page 4, line 15. Nothing in Ring teaches or suggests this use in processes such as appellants claim, and nothing in any of the Examiner's Actions cites any portion of Ring or any other reference which teaches or suggests it.

Because a parallel light source is not required, the light source can be a point source such as a laser diode. Application page 10, lines 11-12. Lenses are not required and if used they can be less complex than in systems which seek to produce parallel light rays. Application page 5, line 21-page 6, line 2. As the attached declaration of inventor Dr. Blohm, filed on December 4, 2001, before - the February 2, 2002 Action (Exhibit C hereto) shows, the use of Fresnel theory to analyze intensity patterns from light assumed to have a nonplanar wavefront now makes it possible to provide a measuring device that can fit in the palm of the hand. That declaration attaches a copy of a sales brochure for the "Inline

2000" Laser 2010XY/Laser 2025XY gauge heads marketed by Appellants' company, Sikora Industrieelektronik GmbH.

Furthermore, each of the four independent claims presented above adds additional limitations to the invention claimed therein. Independent claim 25 adds that distances between the source, article and array are selected such that the intensity pattern in the vicinity of one shadow edge cast by the article on the array is at most negligibly superimposed on the intensity pattern in the vicinity of the other shadow edge cast by the article on the array. (Application p. 5, lines 16 -19) Claim 43 adds that limitation and, among others, that determination of the dimension of the article includes compensating for the difference between (i) the dimension of the article that casts the intensity pattern; and (ii) the diameter of the article. (Application p. 4, line 22 - p. 5, line 2) Claim 49 requires at least two sources and two sensors. (Application fig. 4; p. 12, line 19 - p. 13, line 7) Claim 63 adds the limitation that signals from the sensors corresponding to light intensity in the intensity pattern in order to attenuate effects of dirt. (Application, p. 6, line 20 - p. 7, line 7; p. 12, lines 1 - 10). Quite clearly, none of the inventions claimed in independent claims 25, 43, 49 or 63, with these limitations, are disclosed or suggested in the references cited in this application.

d. Obviousness Not Established.

(1) No prima facie case of obviousness established. Not only do the French reference (geometrical measurement) and the Ring patent (parallel light diffraction analysis) disclose divergent techniques and devices for

measuring dimensions of articles. Not only does the Ring patent expressly distinguish itself from the French reference geometrical types of geometrical measurement techniques. It is also the case that nothing in either of them shows any suggestion of the notion that diffraction patterns should be created and analyzed using processes that only require small and structurally simple systems which assume the light to be a non-planar wave front light phenomenon to measure dimensions of an article. As discussed above, Ring discloses an elaborate structure intended to produce parallel light, and is thus inherently antithetical to the notion of using a small light source to create the more complex non-planar wavefront of light. In any event, there is simply no text from which an inference can be permissibly drawn, much less any express discussion that would provide incentive, suggestion or teaching to combine the Ring parallel light diffraction pattern analysis techniques with the French reference geometrical technique.

The Examiner's Actions in this case have simply failed to deal with this issue. They have failed to address, despite the point being made expressly and in detail in every paper filed by appellants since the Preliminary Amendment in this matter in December 2001, the many ways in which Ring's use of parallel light for diffraction pattern analysis is fundamentally different from the French patent's use of non-planar wavefront light / geometrical approach, and from the present invention's use of non-planar wavefront light with Fresnel diffraction pattern analysis to measure objects. These Actions have utterly failed to adduce any

showing or suggestion in either of the French Reference of Ring of at least the following highlighted substantive, meaningful and patentably distinguishable limitations in each of claims 25, 43, 49 and 63:

Claim 25: A process for measuring a dimension of an elongated, generally cylindrically-shaped article, comprising:

a. illuminating a portion of the article using a light source which casts a beam with nonplanar wavefront onto the article;

b. receiving said nonplanar wavefront beam on a light sensor array, the article interposed between the array and the light source so that the beam and the article create a intensity pattern as received by

the array, the intensity pattern corresponding to a dimension of the article;

c. obtaining from said array a plurality of signals corresponding to light intensity at a plurality of locations in said intensity pattern on said array; and

d. determining said dimension by evaluating information from said signals corresponding to light intensity at a plurality of locations in said intensity pattern in accordance with Fresnel diffraction theory, and according to the assumption that the wavefront from the light source is nonplanar; and

e. wherein distances between the source, the article and the array are selected such that the intensity pattern in the vicinity of one shadow edge cast by the article on the array is at most negligibly

superimposed on th_ intensity pattern in the vicinity of the other shadow edge cast by the article on the array.

Claim 43: A process for measuring a diameter of an elongated article, comprising:

a. illuminating a portion of the article using a light source which casts a beam with nonplanar wavefront onto the article;

b. receiving said nonplanar wavefront beam on a light sensor array containing a plurality of elements, the article interposed between the array and the light source so that the beam and the article create a intensity pattern as received by the array, the intensity pattern corresponding to a dimension of the article that casts the intensity pattern on the array and the intensity pattern having at least two diffraction patterns;

c. obtaining from said array a plurality of signals, each signal corresponding to light intensity from said beam at the location of an element on said array;

d. determining the distance between the article and a member selected from the group of the light source and the array;

e. determining said dimension by evaluating (a) information corresponding to said distance and (b) information from said signals corresponding to light intensity at a plurality of locations in said intensity pattern in accordance with Fresnel diffraction theory, and according to the assumption that the wavefront from the light source is nonplanar;

f. in the process of said determination of said diameter, compensating for the difference between (i) said dimension that casts the intensity pattern on the array and (ii) the diameter of the article; and

g. wherein distances between the source, the article and the array are selected such that the intensity pattern in the vicinity of one shadow edge cast by the article on the array is at most negligibly superimposed on the intensity pattern in the vicinity of the other shadow edge cast by the article on the array.

Claim 49: A process for measuring a dimension of an article, comprising;

a. illuminating a portion of the article using a first light source which casts a first beam with a nonplanar wavefront onto the article;

b. receiving said first beam on a first light sensor array containing a plurality of elements, the article interposed between the first array and the first light source so that the first beam and the article create a first intensity pattern as received by the first array, the first intensity pattern corresponding to the dimension of the article;

c. obtaining from a plurality of elements in said first array a set of first signals corresponding to light intensity from said first beam at a plurality of locations in said first intensity pattern on said first array;

d. illuminating a portion of the article using a second light source which casts a second beam with a nonplanar wavefront onto the article;

e. receiving said second b_am on a second light sensor array containing a plurality of elements, the article interposed between the second array and the second light source so that the second beam and the article create a second intensity pattern as received by the second array, the second intensity pattern also corresponding to the dimension of the article;

f. obtaining from a plurality of elements in said second array a set of second signals corresponding to light intensity from said second beam at a plurality of locations in said second intensity pattern on said second array; and

g. determining said dimension by evaluating information from at least one of said first and second sets of signals corresponding to light intensity at a plurality of locations in said first and second intensity patterns in accordance with Fresnel diffraction theory the determination conducted according to the assumption that the wavefront from the light source is nonplanar;

h. wherein determination of said dimension takes into account the difference between the actual dimension of the article and the dimension of a shadow cast on at least one array by the article, the difference being caused at least in part by the beam having a nonplanar wavefront.

Claim 63: A process for measuring a dimension of an elongated, generally cylindrically-shaped article, comprising:

a. illuminating a portion of the article using a light source which casts a beam with nonplanar wavefront onto the article;

b. receiving said nonplanar wavefront beam on a light sensor array, the article interposed between the array and the light source so that the beam and the article create a intensity pattern as received by the array, the intensity pattern corresponding to a dimension of the article;

c. obtaining from said array a plurality of signals corresponding to light intensity at a plurality of locations in said intensity pattern on said array; and

d. determining said dimension by evaluating information from said signals corresponding to light intensity at a plurality of locations in said intensity pattern in accordance with Fresnel diffraction theory, and according to the assumption that the wavefront from the light source is nonplanar; and

e. filtering said signals corresponding to light intensity at a plurality of locations in said intensity pattern in order to attenuate effects of dirt.

(2) Ring teaches away from the French Reference. In fact, ***Ring teaches away*** from combining the French reference geometrical or light ray-based measuring technique with diffraction pattern measuring techniques. Column 1, lines 15-28 of Ring specifically recognizes the existence of prior art

optical electronic measuring methods which utilize the shadow produced by a work piece, such as in the French reference. It recognizes that these prior art measuring methods, such as the French reference, use geometrical (ray) optics as opposed to wave optics. Ring, Column 1, lines 22-23; column 1, lines 26 - 34 and column 2, lines 21 - 25. But instead of seeking to improve on such techniques, Ring rejects them: Among other reasons, Ring says that such geometrical (ray) methods often require that precise distances be maintained between the light source, the work piece and the sensor so as to avoid an unfavorable effect on precision if the distances cannot be maintained. It also says at column 1, lines 38-46, that such prior art geometrical (ray) techniques as in the French reference require the light sensors to have a high capacity of resolution. Ring notes that apart from unavailability of such sensors in many cases, seeking to compensate mathematically using purely geometrical (ray)techniques, as in the French reference, detracts from reliability of the measuring results. Id. Accordingly, Ring places the French reference type geometrical (ray) optic solution in a separate category from its own wave optic solution and rejects the geometric (ray) optic solution rather than combining such geometrical (ray) optic techniques with wave optic techniques. Ring Column 1, line 18-46.

(3) No suggestion in either the French Reference or Ring that they should be combined. In any event, there is absolutely no suggestion in either the French Reference or Ring that the two references should be combined to arrive at Appellants' invention. Nor has the Examiner pointed to any

such purported showing. Cases are legion that absence of any suggestion to combine references, as here, is fatal to an obviousness determination. *Northern Telecom, Inc. v. Data Point Corp.*, 908 F.2d 931, 934 (Fed. Cir. 1990) (affirming district court holding that claims had not been proved invalid as obvious and holding that the patent challenger must present evidence of some teaching, suggestion or incentive supporting a combination of references). Beyond that, and without belaboring this document with a plethora of citations, it is clear that references which teach away from one another only strengthen the nonobviousness case. Accordingly, the Actions to date have failed to establish a prima facia case that the pending claims are obvious.

CONCLUSION

In view of the foregoing, the Examiner's rejections of Claims 25-80 were erroneous and reversal of his decision is respectfully requested.

Respectfully submitted,

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In Re Application of:	Werner Blohm, Harald Sikora and Adrian Beining
Serial No. of Parent Application:	10/008,998
Filing date of Parent Application:	December 4, 2001
For:	METHOD OF MEASURING THE DIAMETER OF AN ELONGATED ARTICLE OF A CIRCULAR CROSS SECTION
Examiner:	Richard A. Rosenberger
Group Art Unit:	2877

Appendix A

CLAIMS ON APPEAL

25. A process for measuring a dimension of an elongated, generally cylindrically-shaped article, comprising:

a. illuminating a portion of the article using a light source which casts a beam with nonplanar wavefront onto the article;

b. receiving said nonplanar wavefront beam on a light sensor array, the article interposed between the array and the light source so that the beam and the article create a intensity pattern as received by the array, the intensity pattern corresponding to a dimension of the article;

c. obtaining from said array a plurality of signals corresponding to light intensity at a plurality of locations in said intensity pattern on said array; and

d. determining said dimension by evaluating information from said signals corresponding to light intensity at a plurality of locations in said intensity pattern in accordance with Fresnel diffraction theory, and according to the assumption that the wavefront from the light source is nonplanar; and

e. wherein distances between the source, the article and the array are selected such that the intensity pattern in the vicinity of one shadow edge cast by the article on the array is at most negligibly superimposed on the intensity pattern in the vicinity of the other shadow edge cast by the article on the array.

26. The process of claim 25 wherein evaluating information from said signals is accomplished using information that corresponds to a plurality of characteristic feature points in at least one diffraction pattern in the intensity pattern.

27. The process of claim 26 wherein said characteristic feature points are selected from a group comprising turning points, local centroids, local intensity maxima and local intensity minima in said at least one pattern.

28. The process of claim 25 wherein evaluating information from said signals is accomplished using information that corresponds to a gradient between predetermined characteristic feature points in at least one diffraction pattern in the intensity pattern.

29. The process of claim 25 wherein evaluating information from said signals is accomplished by comparing said information to information corresponding to a

reference intensity pattern determined in accordance with Fresnel diffraction theory.

30. The process of claim 25 wherein evaluating information from said signals is accomplished by comparing said information to a plurality of reference intensity patterns determined in accordance with Fresnel diffraction theory.

31. The process of claim 25 wherein the dimension of the article is a diameter of an elongated article.

32. The process of claim 31 wherein the article is moving when its diameter is measured.

33. The process of claim 25 wherein the light source produces monochromatic light.

34. The process of claim 25 wherein at least one contamination-reducing member is interposed between the article and at least one of the array and the light source, said at least one member selected from the group comprising electrostatic apertures, non-electrostatic apertures, compressed gas nozzles and transparent material.

35. The process of claim 25 wherein a transparent material is interposed between said article and at least one of said array and said light source.

36. The process of claim 25 wherein determination of said dimension takes into account the difference between the actual dimension of the article and the dimension of a shadow cast on the array by the article, the difference being caused at least in part by the beam having a nonplanar wavefront.

37. The process of claim 36 wherein determination taking into account said difference includes proportionally compensating for the distance of the article from a member selected from the group of the light source and the array.

38. The process of claim 36 wherein said determination of said dimension includes compensating for the difference between (i) a dimension of the article that casts the shadow on the array and (ii) said dimension of the article that is actually desired to be determined.

39. The process of claim 25 using at least two light sources.

40. The process of claim 25 using at least two light sources and two arrays.

41. The process of claim 25 using two light sources and two arrays, wherein the beams cast by the light sources are substantially perpendicular to each other.

42. The process of claim 41 wherein determination of said dimension relies upon a value corresponding to a distance between an array and the article, and said value is derived using information from said two arrays.

43. A process for measuring a diameter of an elongated article, comprising:

a. illuminating a portion of the article using a light source which casts a beam with nonplanar wavefront onto the article;

b. receiving said nonplanar wavefront beam on a light sensor array containing a plurality of elements, the article interposed between the array and the light source so that the beam and the article create a intensity pattern as received by the array, the intensity pattern corresponding to a dimension of the

article that casts the intensity pattern on the array and the intensity pattern having at least two diffraction patterns;

c. obtaining from said array a plurality of signals, each signal corresponding to light intensity from said beam at the location of an element on said array;

d. determining the distance between the article and a member selected from the group of the light source and the array;

e. determining said dimension by evaluating (a) information corresponding to said distance and (b) information from said signals corresponding to light intensity at a plurality of locations in said intensity pattern in accordance with Fresnel diffraction theory, and according to the assumption that the wavefront from the light source is nonplanar;

f. in the process of said determination of said diameter, compensating for the difference between (i) said dimension that casts the intensity pattern on the array and (ii) the diameter of the article; and

g. wherein distances between the source, the article and the array are selected such that the intensity pattern in the vicinity of one shadow edge cast by the article on the array is at most negligibly superimposed on the intensity pattern in the vicinity of the other shadow edge cast by the article on the array.

44. The process of claim 43 wherein evaluating information from said signals is accomplished using information that corresponds to a plurality of characteristic feature points in at least one diffraction pattern in the intensity pattern.

45. The process of claim 44 wherein said characteristic feature points are selected from a group comprising turning points, local centroids, local intensity maxima and local intensity minima in said at least one pattern.

46. The process of claim 43 wherein evaluating information from said signals is accomplished using information that corresponds to a gradient between predetermined characteristic feature points in at least one diffraction pattern in the intensity pattern.

47. The process of claim 43 wherein evaluating information from said signals is accomplished by comparing said information to information corresponding to a reference intensity pattern determined in accordance with Fresnel diffraction theory.

48. The process of claim 43 wherein evaluating information from said signals is accomplished by comparing said information to a plurality of reference intensity patterns determined in accordance with Fresnel diffraction theory.

49. A process for measuring a dimension of an article, comprising;

a. illuminating a portion of the article using a first light source which casts a first beam with a nonplanar wavefront onto the article;

b. receiving said first beam on a first light sensor array containing a plurality of elements, the article interposed between the first array and the first light source so that the first beam and the article create a first intensity pattern as received by the first array, the first intensity pattern corresponding to the dimension of the article;

c. obtaining from a plurality of elements in said first array a set of first signals corresponding to light intensity from said first beam at a plurality of locations in said first intensity pattern on said first array;

d. illuminating a portion of the article using a second light source which casts a second beam with a nonplanar wavefront onto the article;

e. receiving said second beam on a second light sensor array containing a plurality of elements, the article interposed between the second array and the second light source so that the second beam and the article create a second intensity pattern as received by the second array, the second intensity pattern also corresponding to the dimension of the article;

f. obtaining from a plurality of elements in said second array a set of second signals corresponding to light intensity from said second beam at a plurality of locations in said second intensity pattern on said second array; and

g. determining said dimension by evaluating information from at least one of said first and second sets of signals corresponding to light intensity at a plurality of locations in said first and second intensity patterns in accordance with Fresnel diffraction theory the determination conducted according to the assumption that the wavefront from the light source is nonplanar;

h. wherein determination of said dimension takes into account the difference between the actual dimension of the article and the dimension of a shadow cast on at least one array by the article, the difference being caused at least in part by the beam having a nonplanar wavefront.

50. The process of claim 49 wherein evaluating information from said signals is accomplished using information that corresponds to a plurality of characteristic feature points in at least one diffraction pattern in at least one of said intensity patterns.

51. The process of claim 50 wherein said characteristic feature points are selected from a group comprising turning points, local centroids, local intensity maxima and local intensity minima in said at least one pattern.

52. The process of claim 49 wherein evaluating information from said signals is accomplished using information that corresponds to a gradient between predetermined characteristic feature points in at least one diffraction pattern in at least one of the intensity patterns.

53. The process of claim 49 wherein evaluating information from said signals is accomplished by comparing said information to information corresponding to a reference intensity pattern determined in accordance with Fresnel diffraction theory.

54. The process of claim 49 wherein evaluating information from said signals is accomplished by comparing said information to a plurality of reference intensity patterns determined in accordance with Fresnel diffraction theory.

55. The process of claim 49 wherein the dimension is a diameter and wherein the article is moving when its diameter is measured.

56. The process of claim 49 wherein the light sources produce monochromatic light.

57. The process of claim 49 wherein at least one contamination-reducing member is interposed between the article and at least one of the array and the light source, said at least one member selected from the group comprising electrostatic devices, non-electrostatic apertures, compressed gas nozzles, creation of an overpressure and transparent material.

58. The process of claim 49 wherein transparent material is interposed between said article and at least one of said array and said light source.

59. The process of claim 49 wherein said determination of said dimension takes into account distance of the article relative to at least one member selected from the group comprising said light sources and said arrays, and wherein information corresponding to said distance is determined from at least one of said first and second sets of signals.

60. The process of claim 59 wherein said determination of said dimension relies upon a value corresponding to a distance between an array and the article.

61. The process of claim 49 wherein distances between the sources, the article and the arrays are selected such that the intensity patterns in the vicinity of one shadow edge cast by the article on each array is at most negligibly superimposed on the intensity pattern in the vicinity of the other shadow edge cast by the article on the array.

62. The process of claim 49 wherein said determination of said dimension includes compensating for the difference between (i) a dimension of the article

that casts the shadow on the array and (ii) said dimension of the article that is actually desired to be determined.

63. A process for measuring a dimension of an elongated, generally cylindrically-shaped article, comprising:

a. illuminating a portion of the article using a light source which casts a beam with nonplanar wavefront onto the article;

b. receiving said nonplanar wavefront beam on a light sensor array, the article interposed between the array and the light source so that the beam and the article create a intensity pattern as received by the array, the intensity pattern corresponding to a dimension of the article;

c. obtaining from said array a plurality of signals corresponding to light intensity at a plurality of locations in said intensity pattern on said array; and

d. determining said dimension by evaluating information from said signals corresponding to light intensity at a plurality of locations in said intensity pattern in accordance with Fresnel diffraction theory, and according to the assumption that the wavefront from the light source is nonplanar; and

e. filtering said signals corresponding to light intensity at a plurality of locations in said intensity pattern in order to attenuate effects of dirt.

64. The process of claim 63 wherein evaluating information from said signals is accomplished using information that corresponds to a plurality of characteristic feature points in at least one diffraction pattern in the intensity pattern.

65. The process of claim 64 wherein said characteristic feature points are selected from a group comprising turning points, local centroids, local intensity maxima and local intensity minima in said at least one pattern.

67. The process of claim 63 wherein evaluating information from said signals is accomplished using information that corresponds to a gradient between predetermined characteristic feature points in at least one diffraction pattern in the intensity pattern.

67. The process of claim 63 wherein evaluating information from said signals is accomplished by comparing said information to information corresponding to a reference intensity pattern determined in accordance with Fresnel diffraction theory.

68. The process of claim 63 wherein evaluating information from said signals is accomplished by comparing said information to a plurality of reference intensity patterns determined in accordance with Fresnel diffraction theory.

69. The process of claim 63 wherein the dimension of the article is a diameter of an elongated article.

70. The process of claim 69 wherein the article is moving when its diameter is measured.

71. The process of claim 63 wherein the light source produces monochromatic light.

72. The process of claim 63 wherein at least one contamination-reducing member is interposed between the article and at least one of the array and the

light source, said at least one member selected from the group comprising electrostatic apertures, non-electrostatic apertures, compressed gas nozzles and transparent material.

73. The process of claim 63 wherein a transparent material is interposed between said article and at least one of said array and said light source.

74. The process of claim 63 wherein determination of said dimension takes into account the difference between the actual dimension of the article and the dimension of a shadow cast on the array by the article, the difference being caused at least in part by the beam having a nonplanar wavefront.

75. The process of claim 74 wherein determination taking into account said difference includes proportionally compensating for the distance of the article from a member selected from the group of the light source and the array.

76. The process of claim 74 wherein said determination of said dimension includes compensating for the difference between (i) a dimension of the article that casts the shadow on the array and (ii) said dimension of the article that is actually desired to be determined.

77. The process of claim 63 using at least two light sources.

78. The process of claim 63 using at least two light sources and two arrays.

79. The process of claim 63 using two light sources and two arrays, wherein the beams cast by the light sources are substantially perpendicular to each other.

80. The process of claim 79 wherein determination of said dimension relies upon a value corresponding to a distance between an array and the article, and said value is derived using information from said two arrays.

EXHIBIT A

RÉPUBLIQUE FRANÇAISE

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A1

DEMANDE DE BREVET D'INVENTION

(21) N° 76 35004

(54) Procédé et dispositif de mesure dynamique du diamètre d'un fil sous forme numérique.

(51) Classification internationale (Int. Cl.²). G 01 B 11/10.

(22) Date de dépôt .... 19 novembre 1976, à 16 h 2 mn.

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(71) Déposant : Société dite : SOCIETE INDUSTRIELLE DE LIAISONS ELECTRIQUES — SILEC. Société anonyme, résidant en France.

(72) Invention de :

(73) Titulaire : *Idem* (71)

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La présente invention concerne un procédé et un dispositif de mesure dynamique du diamètre d'un fil sous forme numérique et, plus particulièrement, d'un fil ou d'un conducteur isolé en déplacement.

Dans l'art antérieur, on utilisait pour cette mesure un dispositif optique qui projetait l'image du fil, éventuellement agrandie, sur une cellule photo-électrique qui fournissait une tension proportionnelle à la dimension de l'image projetée du fil c'est-à-dire à son diamètre. Ce procédé de l'art antérieur était sujet à des erreurs dues notamment aux variations suivantes :

- luminosité de la source éclairante ;
- transmission optique du milieu qui peut être plus ou moins opacifié par des poussières ou des projections de particules solides ou liquides;
- transparence de la fenêtre de la cellule pour les mêmes raisons;
- instabilité de la cellule en fonction de la température ou par vieillissement.

Un objet de la présente invention est de prévoir un nouveau procédé de mesure dynamique du diamètre d'un fil permettant d'éviter les inconvénients ci-dessus.

Un autre objet de la présente invention est de prévoir un tel procédé permettant une mesure sous forme numérique.

Un autre objet de la présente invention est de prévoir un tel procédé permettant une mesure pratiquement instantanée.

Un autre objet de la présente invention est de prévoir un dispositif mettant en oeuvre le procédé ci-dessus.

Le procédé de mesure dynamique du diamètre d'un fil sous forme numérique selon la présente invention comprend notamment les étapes consistant à : éclairer ce fil selon une première direction par une source lumineuse ponctuelle ou linéaire et parallèle au fil de façon à former un dièdre d'ombre; disposer dans un premier plan coupant ce dièdre d'ombre, sensiblement à la limite de chacun des bords de la projection du fil et perpendiculairement à cette limite, deux détecteurs linéaires à cellules élémentaires; compter à divers instants souhaités le nombre de cellules non éclairées des deux détecteurs; et additionner ces deux nombres et un nombre correspondant à la distance constante entre les deux détecteurs d'où il résulte une

mesure instantanée du diamètre du fil.

Pour éviter les erreurs dues aux vibrations du fil, dans une direction normale à celle du plan de mesure, on pourra ou bien amortir mécaniquement le fil dans cette direction, ou bien utiliser le procédé consistant à : éclairer le fil selon une seconde direction sensiblement perpendiculaire à la première direction ; disposer dans un second plan de mesure orthogonal au premier un troisième photodétecteur linéaire à cellules élémentaires perpendiculairement à la limite d'un bord de l'ombre portée du fil dans ce second plan ; compter les cellules non éclairées de ce détecteur, et utiliser l'information résultant de ce comptage pour corriger le résultat de la mesure faite par le procédé selon la présente invention, en fonction de la position instantanée du fil dans une direction normale à celle du premier plan de mesure.

Pour mettre en oeuvre le procédé selon la présente invention, on utilise un dispositif de mesure numérique des dimensions de l'ombre portée d'un fil sur un écran comprenant deux photodétecteurs linéaires à cellules élémentaires disposés perpendiculairement à chacune des limites de la zone d'ombre et à cheval sur chacune de ces limites, et des moyens pour compter à tout instant souhaité le nombre de cellules situées dans la zone d'ombre.

On va décrire ci-après des modes de réalisation particuliers de la présente invention dans lesquels les photodétecteurs linéaires à cellules élémentaires sont des dispositifs photosensibles à transfert de charge couramment désignés dans la technique par le sigle CCD d'après leur appellation anglaise (Charge Coupled Device). Ces détecteurs photosensibles peuvent être considérés comme des registres à décalage dans chacune des cases ou des cellules desquelles des charges peuvent être accumulées par suite d'un éclairement et proportionnellement à l'intensité de cet éclairement. De tels dispositifs sont disponibles commercialement, par exemple auprès de la société dite Fairchild Corporation, sous la dénomination commerciale CCD1.

Une description détaillée de modes de réalisation particuliers de la présente invention va être donnée ci-dessous à titre d'exemple en relation avec les dessins joints dans lesquels :

La figure 1 représente schématiquement l'agencement d'un dispositif de mesure dynamique du diamètre d'un fil ;

La figure 2 illustre à titre de comparaison et d'exemple

schématique le contenu d'un dispositif photosensible selon la présente invention ; et

La figure 3 représente un deuxième mode de réalisation de la présente invention dans le cas où le fil est muni d'une gaine translucide.

En figure 1, une source lumineuse 1 éclaire un fil 2 en déplacement dans un sens perpendiculaire au plan de la figure, ce déplacement étant éventuellement très rapide et le fil étant soumis à des vibrations. La source lumineuse est une source ponctuelle ou linéaire parallèle au fil, c'est-à-dire dans un sens perpendiculaire au plan de la figure. Il se forme ainsi un dièdre d'ombre et l'on peut observer sur un écran 3 une bande d'ombre parallèle au fil 2. Aux deux limites de cette bande d'ombre, et à cheval sur chacune de ces limites, sont disposés des photodétecteurs linéaires 4 et 5. La dimension de ces photodétecteurs linéaires est choisie pour que, au cours des vibrations du fil dans le sens parallèle au plan de mesure, les limites de la zone d'ombre restent dans la plupart des cas à l'intérieur des dimensions des photodétecteurs linéaires 4 et 5.

La source lumineuse devra émettre une longueur d'onde optique compatible avec la réponse spectrale des photodétecteurs linéaires 4 et 5 et des précautions devront être prises pour que la lumière parasite n'agisse pas. On pourra, par exemple, prévoir un boîtier opaque ou encore choisir une longueur d'onde de source 1 monochromatique et faire précéder chacun des photodétecteurs d'un filtre monochromatique très sélectif approprié. Ainsi, la lumière parasite n'aura que peu d'influence. La source lumineuse 1 peut, par exemple, être une diode électroluminescente qui présente une grande durée de vie et qui est peu sensible aux vibrations ce qui constitue un avantage important dans un environnement d'atelier de fabrication.

Les photodétecteurs linéaires 4 et 5 du type à transfert de charge peuvent être considérés comme formés de n cellules élémentaires alignées. Ces cellules se chargent chacune proportionnellement à la quantité de lumière qu'elles reçoivent. Pour effectuer la lecture, les deux photodétecteurs ou registres 4 et 5 sont décalés séquentiellement dans le sens indiqué par les flèches 6 et 7 de sorte que le contenu de la cellule 1 située dans la zone d'ombre de chacun de ces registres soit extrait en premier. En disposant à la sortie du registre un comparateur suivi d'un compteur, on peut compter suc-

cessivement toutes les cellules dans lesquelles le niveau est inférieur à un niveau de seuil correspondant au niveau de noir, et arrêter le comptage dès que l'on arrive à une cellule dont le niveau est supérieur à un niveau de seuil correspondant à une cellule éclairée.

Cette exploration doit être faite suffisamment vite pour qu'il n'y ait pas eu de modification de l'ombre portée du fil au cours de la mesure en raison des vibrations du fil. On notera que cette exigence est facilement satisfaite selon la présente invention étant donné que d'une part la fréquence d'horloge peut être égale à quelques mégahertz et d'autre part que les deux registres sont lus simultanément en partant de la zone d'ombre. Ceci assure une rapidité bien supérieure à celle envisageable pour les vibrations du fil. Ainsi, on obtient comme résultat de la mesure que n_1 cellules du registre photosensible 4 était dans l'obscurité ainsi que n_2 cellules du registre photosensible 5 à un instant donné auquel a été effectuée la mesure. En tenant compte du facteur d'échelle et de la distance b entre les registres 4 et 5, on obtiendra ainsi un nombre proportionnel au diamètre du fil, le facteur de proportionnalité étant p/p_1, p étant la distance entre la source lumineuse 1 et l'écran 3 et p_1 la distance entre le fil et la source lumineuse. Bien entendu, dans ce qui précède, on a supposé que la distance p_1 était constante, c'est-à-dire que des moyens mécaniques par exemple étaient prévus pour empêcher le fil de vibrer dans une direction normale à l'écran 3.

A titre d'exemple, un registre photosensible à transfert de charge actuellement commercialisé est constitué de cellules distantes de 13 microns. Si l'on dispose d'un agrandissement optique de 13 fois, chaque cellule de chacun des registres photosensibles 4 et 5 représentera un micron de diamètre pour le fil. Le diamètre en microns du fil sera donc le nombre de cases noires du registre 4 plus le nombre de cases noires du registre 5 plus b en microns divisé par 13. Soit : $n_1 + n_2 + b\ (\mu)/13$.

On a décrit précédemment un moyen de mesure numérique du diamètre d'un fil et de ses variations. On notera toutefois que, s'il s'agit là d'un mode de réalisation préféré de la présente invention. Les registres photosensibles 4 et 5 du type à transfert de charge sont, quant au contenu de chacune de leurs cases, des dispositifs

analogiques. Il est donc possible au lieu de transmettre la sortie de chacun de ces registres à des compteurs par l'intermédiaire d'un comparateur fixant un niveau de seuil, de transférer le contenu des registres 4 et 5 dans des registres intermédiaires non photosensibles ou protégés par rapport à la lumière et de mesurer ensuite les tensions dans chacune des cases de ces registres intermédiaires ou tampons.

La figure 2 représente, à titre d'exemple, des cases du registre photosensible 4. On suppose, comme dans le cas de la figure 1, que les cases 1 à n_1 se trouvent dans l'obscurité, c'est-à-dire qu'aucune charge n'y sera accumulée. La case $n_1 + 1$ est donc à la lumière et c'est à partir de cette case que le comptage sera arrêté. Ainsi, même s'il existe des poussières obscurcissant l'une des cases du registre, par exemple la case $n_1 + 4$, cette poussière n'aura pas d'influence sur cette mesure. Ainsi, dans le cas le plus général, la poussière se trouve, ou bien dans la zone d'ombre, ou bien dans la zone de lumière et n'aura aucune influence sur la mesure. Dans le cas le plus défavorable, la poussière pourra se trouver à la limite des zones d'ombre et de lumière. Même dans ce dernier cas, sa présence se signalera par l'apparition d'un chiffre erratique qui pourra ensuite être éliminé lors du traitement.

On notera également qu'il peut se produire accidentellement une forte vibration du fil 2 qui entraîne les limites de la bande d'ombre à sortir des dimensions des registres photosensibles 4 et 5. Pour éviter d'effectuer des enregistrements erratiques, ce qui se passerait si on faisait un enregistrement précisément à un tel instant, des moyens de validation sont prévus pour inhiber le comptage quand la première cellule du registre 4 ou la première cellule du registre 5 n'est pas "noire". De tels circuits de validation sont facilement réalisables par l'homme de l'art.

Une application envisagée de la présente invention est la surveillance de façon pratiquement continue, c'est-à-dire à intervalles réguliers dans le temps, du diamètre d'un fil au cours de sa fabrication, par exemple, lors de la fabrication de fils électriques ou téléphoniques gainés ou non, ou de fils textiles. En ce cas, il pourra être utile pour l'opérateur de la machine de visualiser sur une échelle lumineuse l'état des cellules des registres 4 et 5. Ainsi, le contenu des cellules pourra être transféré lors de chaque

exploration de ces contenus sur des séries de diodes électroluminescentes (une par cellule). Pour des raisons pratiques, il sera préférable de choisir une échelle simple, par exemple 1 micron = 1 cellule = 1 lampe de visualisation. L'intervalle b représenté en figure 1 pourra également être reproduit sur l'échelle de visualisation par une série de lampes allumées en permanence. On pourra ainsi suivre visuellement l'opération de mesure et repérer les cellules obscurcies, les débordements, les variations de diamètre du fil.

Indépendamment de cette visualisation, on codera les informations issues des registres photosensibles 4 et 5 soit en transformant les informations séries en informations parallèles à l'aide d'un registre à décalage auxiliaire et en effectuant un codage compatible avec l'organe de traitement final par exemple sous forme d'un code binaire pur ou binaire codé décimal, soit en effectuant une transformation numérique/analogique.

Dans les deux cas, et lors d'un procédé de fabrication de fil, on exploitera ces données pour agir sur des asservissements numériques ou analogiques et pour conserver une trace de la mesure afin d'établir des corrélations immédiates ou retardées avec les paramètres de fabrication influant sur le diamètre du fil. Les informations numériques pourront être stockées sur cassette ou disque magnétique et les informations analogiques pourront être transcrites par un enregistreur.

Dans le cas d'informations numériques on pourra utiliser un ordinateur pour effectuer un traitement statistique et mesurer, par exemple, les valeurs moyennes, les écarts types, etc...

On a supposé dans ce qui précède, que le fil ne peut vibrer dans une direction normale au plan de mesure 3. Ceci n'est pas toujours possible dans la pratique. En conséquence, comme cela est représenté en figure 1, on pourra prévoir un dispositif de mesure supplémentaire pour mesurer les variations Δ p_1 de la valeur p_1 et utiliser ce paramètre pour corriger la mesure de diamètre fournie par les registres photosensibles 4 et 5. A titre d'exemple, ce dispositif auxiliaire peut comprendre une source lumineuse 10 suivie d'un objectif 11 projetant l'ombre du fil sur un écran 12. Un troisième registre photosensible 13 permet de détecter les variations de p_1.

La figure 3 représente une variante d'application de la présente invention pour mesurer le diamètre d'un fil 20 revêtu d'une gaine translucide 21. Dans cette figure, les références identiques à celles de la figure 1 désignent des éléments analogues. On trouvera alors sur l'écran, trois niveaux différents : une bande centrale noire, encadrée de bandes grises, le reste étant éclairé à un niveau de blanc. Dans ce cas, au cours du traitement du contenu des registres photosensibles 4 et 5, on utilisera un système ternaire à trois niveaux (0, 1 et 2), le zéro sera défini comme précédemment, le 1 représentera la luminosité du gris et le 2 la zone éclairée sans atténuation.

Pour définir un gris, on pourra en plus du niveau de noir ou bien définir un niveau de blanc et considérer que ce qui n'est ni noir ni blanc est gris, ou bien définir en plus un niveau électrique de gris compris entre deux limites différentes du 0 et du 2 pour éviter des erreurs dues à des dérives de tension. Ce tri des gris sera effectué par un discriminateur à fenêtre de tension. Cette seconde façon de procéder donne une information plus riche qui permettra, entre autres, par totalisation des noirs plus gris plus blancs, de détecter des anomalies telles que des empoussiérages de certaines cases ou cellules si cette somme n'est pas égale au nombre n des cellules des détecteurs linéaires photosensibles 4 et 5.

Bien sûr, de même que dans le cas de la figure 1, on pourra utiliser dans le cas de la figure 3, un détecteur de vibrations normales.

La présente invention n'est pas limitée aux exemples de réalisation qui viennent d'être décrits, elle est au contraire susceptible de variantes et de modifications qui apparaîtront à l'homme de l'art.

REVENDICATIONS

1 - Procédé de mesure dynamique du diamètre d'un fil sous forme numérique, caractérisé en ce qu'il comprend les étapes suivantes :

- éclairer ce fil selon une première direction par une source lumineuse ponctuelle, ou linéaire et parallèle au fil, de façon à former un dièdre d'ombre ;

- disposer dans un premier plan coupant ce dièdre d'ombre, sensiblement à la limite de chacun des bords de l'ombre portée du fil et perpendiculairement à cette limite, deux photodétecteurs linéaires à cellules élémentaires ;

- compter à divers instants souhaités, le nombre de cellules non éclairées des deux détecteurs ;

- additionner ces deux nombres et un nombre correspondant à une distance constante entre les deux détecteurs d'où il résulte une mesure instantanée du diamètre du fil.

2 - Procédé selon la revendication 1, caractérisé en ce que le fil est asservi à ne pouvoir vibrer que dans un plan parallèle au plan de mesure.

3 - Procédé selon la revendication 1, caractérisé en ce qu'il comprend en outre les étapes consistant à :

- éclairer le fil selon une direction sensiblement normale à la première direction ;

- disposer dans un second plan de mesure, orthogonal au premier, un troisième photodétecteur linéaire à cellules élémentaires perpendiculairement à la limite d'un bord de l'ombre portée du fil dans ce second plan ;

- compter les cellules non éclairées de ce troisième détecteur ; et

- utiliser l'information résultant de ce comptage pour corriger le résultat de la mesure selon la revendication 1, d'où il résulte que l'on s'affranchit des composantes vibratoires éventuelles du fil dans une direction normale au premier plan de mesure.

4 - Dispositif de mesure numérique des dimensions de l'ombre portée d'un fil sur un écran, caractérisé en ce qu'il comprend deux photodétecteurs linéaires à cellules élémentaires disposés perpendiculairement à chacune des limites de la zone d'ombre portée du fil et à cheval sur chacune de ces limites, et des moyens pour compter à tout

instant souhaité le nombre de cellules de chacun des photodétecteurs situés dans la zone d'ombre.

5 - Dispositif selon la revendication 4, caractérisé en ce que lesdits photodétecteurs sont des registres à décalage photosensibles linéaires du type à transfert de charge.

6 - Dispositif selon la revendication 5, caractérisé en ce qu'il comprend des moyens d'horloge pour décaler le contenu des registres photosensibles vers des compteurs.

7 - Dispositif selon la revendication 6, caractérisé en ce qu'il comprend des moyens d'inhibition pour inhiber le comptage dans les compteurs quand la première case lue d'un registre contient une information correspondant à un éclairement.

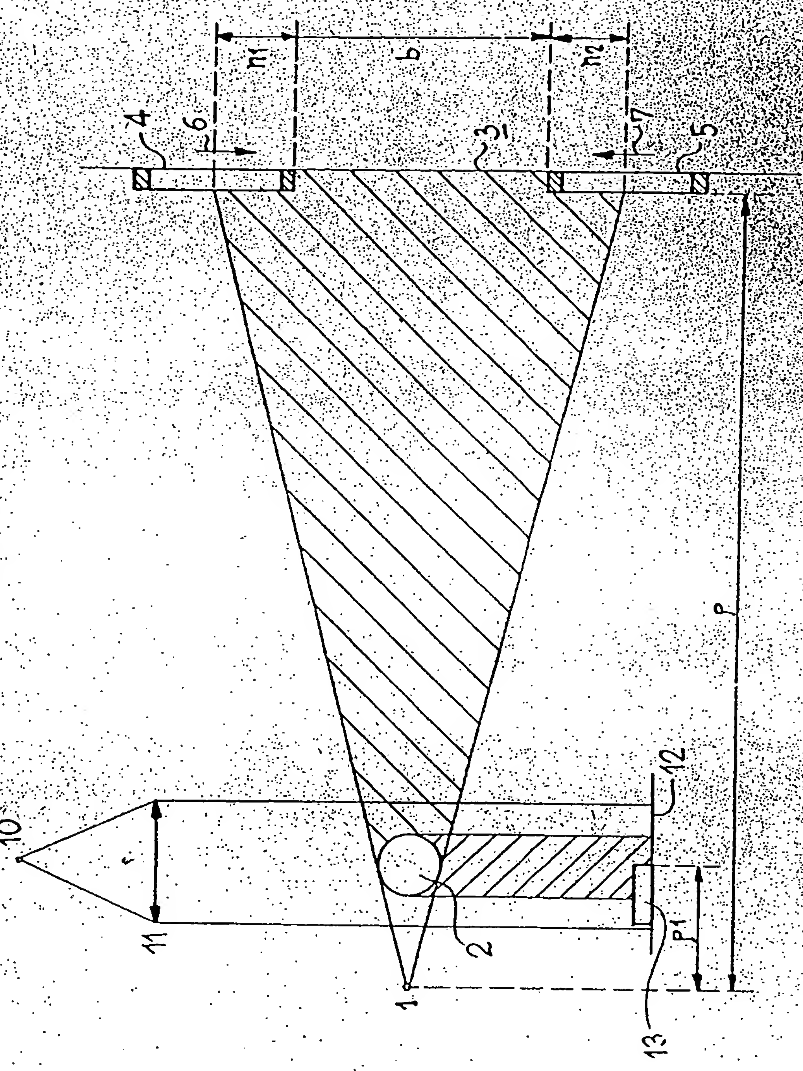
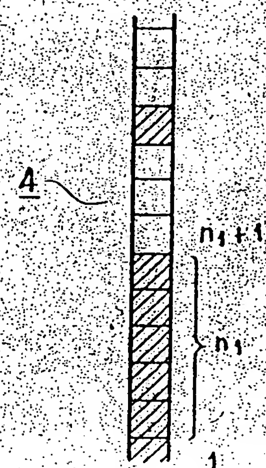


FIG. 1

PL. II/2

FIG. 2



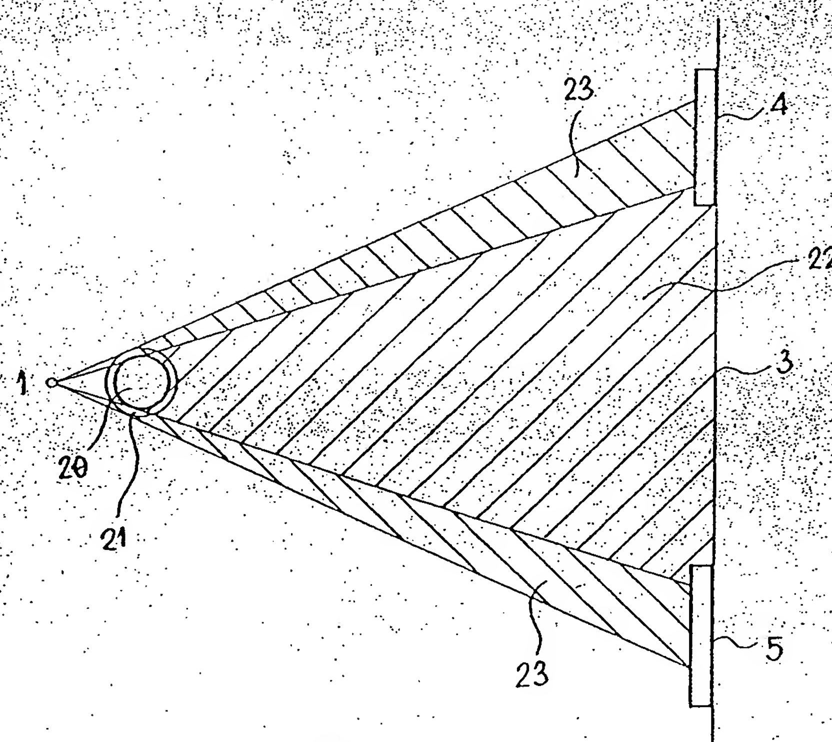


FIG. 3

EXHIBIT B

United States Patent [19]

Ring et al.

[11] **Patent Number:** 4,854,707

[45] **Date of Patent:** Aug. 8, 1989

[54] **METHOD AND APPARATUS FOR THE OPTICAL ELECTRONIC MEASUREMENT OF A WORKPIECE**

[75] Inventors: **Manfred Ring**, Radolfzell; **Jürgen Weber**, Hamburg; **Helmut Ackermann**, Norderstedt, all of Fed. Rep. of Germany

[73] Assignee: **Georg Fischer Aktiengesellschaft**, Schaffhausen, Switzerland

[21] Appl. No.: **213,502**

[22] Filed: **Jun. 27, 1988**

Related U.S. Application Data

[63] Continuation of Ser. No. 810,930, Dec. 18, 1985, abandoned.

[30] **Foreign Application Priority Data**

Dec. 20, 1985 [CH] Switzerland 6071/84

[51] **Int. Cl.⁴** **G01B 9/02**

[52] **U.S. Cl.** **356/356**; 356/387

[58] **Field of Search** 356/354, 355, 356, 384, 356/385, 386, 387, 388

[56] **References Cited**

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Primary Examiner—Vincent P. McGraw
Assistant Examiner—S. A. Turner
Attorney, Agent, or Firm—Marmorek Guttman Rubenstein

[57] **ABSTRACT**

An optical electronic method for the measuring of a workpiece is disclosed. A beam of radiation is used to illuminate an edge of the object to be measured to form an actual diffraction pattern. The actual diffraction pattern is converted to electronic signals by means of a sensor and correlated electronically with a predetermined theoretically calculated diffraction pattern.

14 Claims, 3 Drawing Sheets

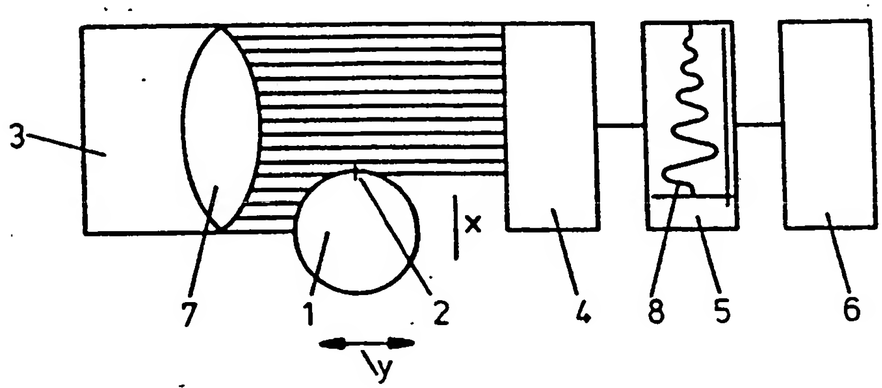


Fig.1

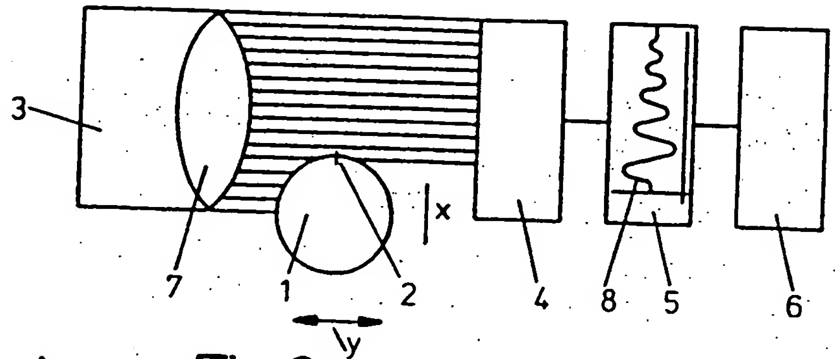


Fig. 2

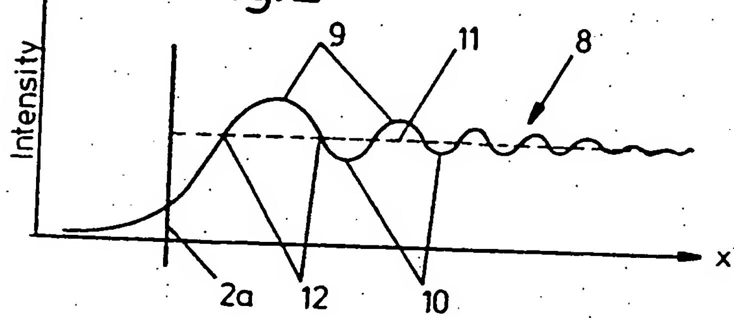


Fig. 3

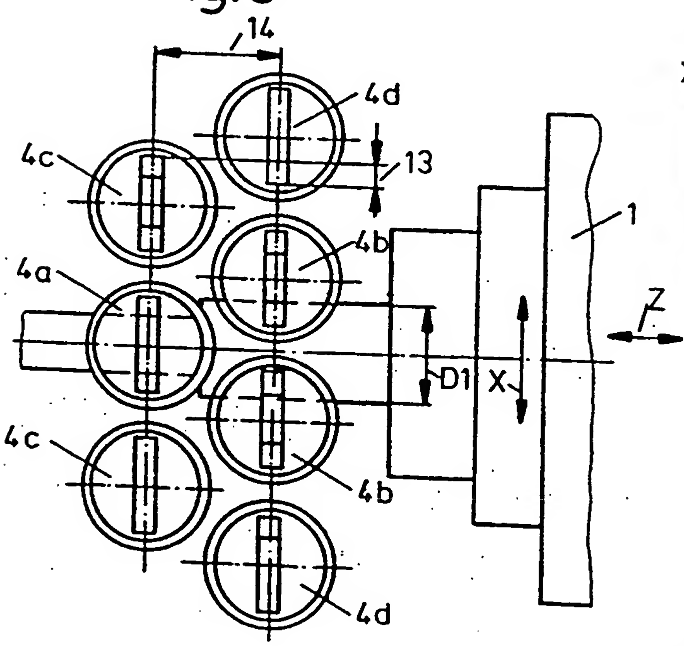


Fig. 4

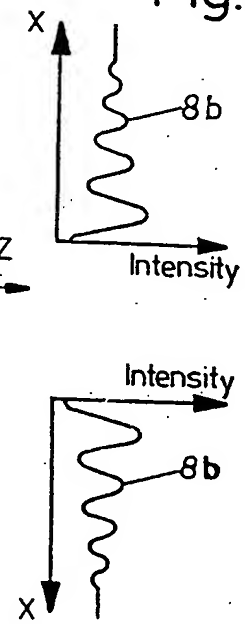
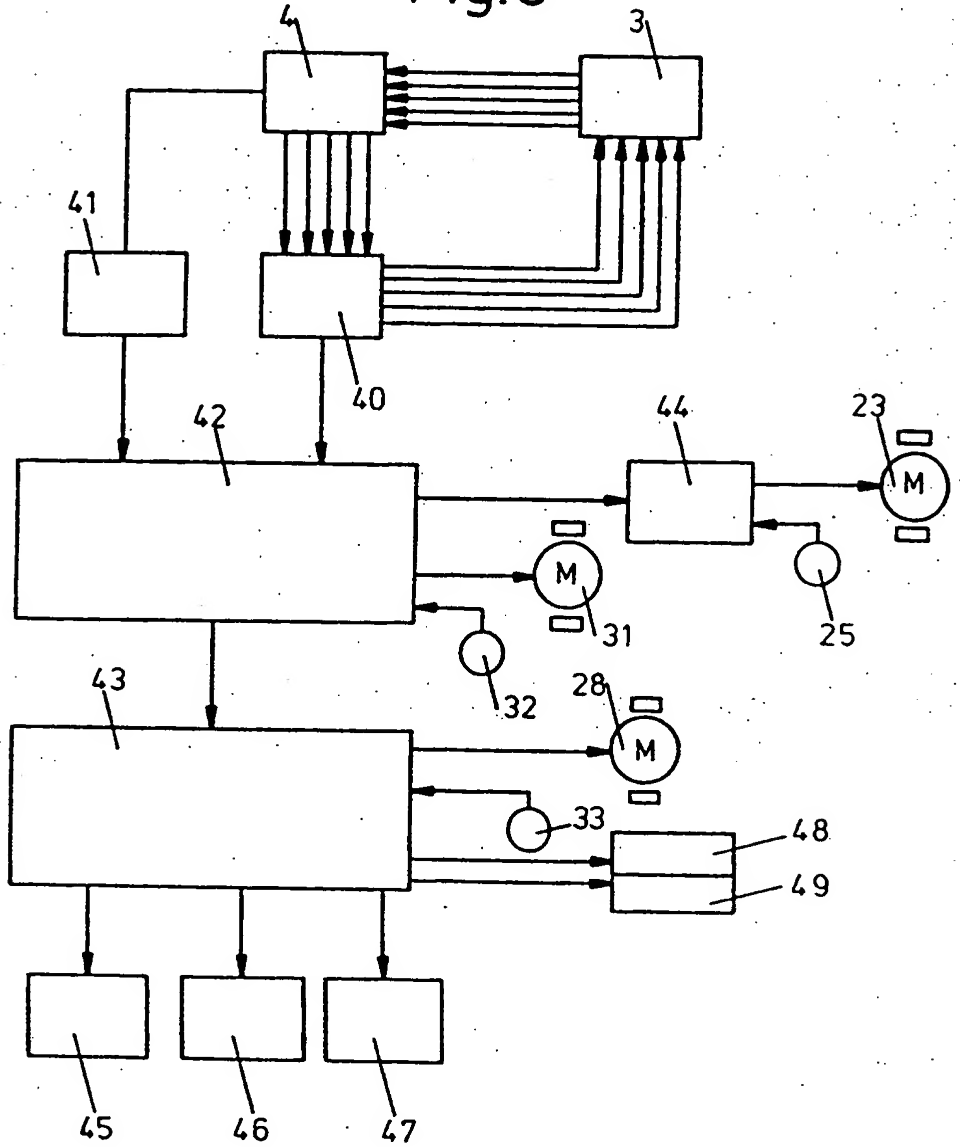


Fig. 5



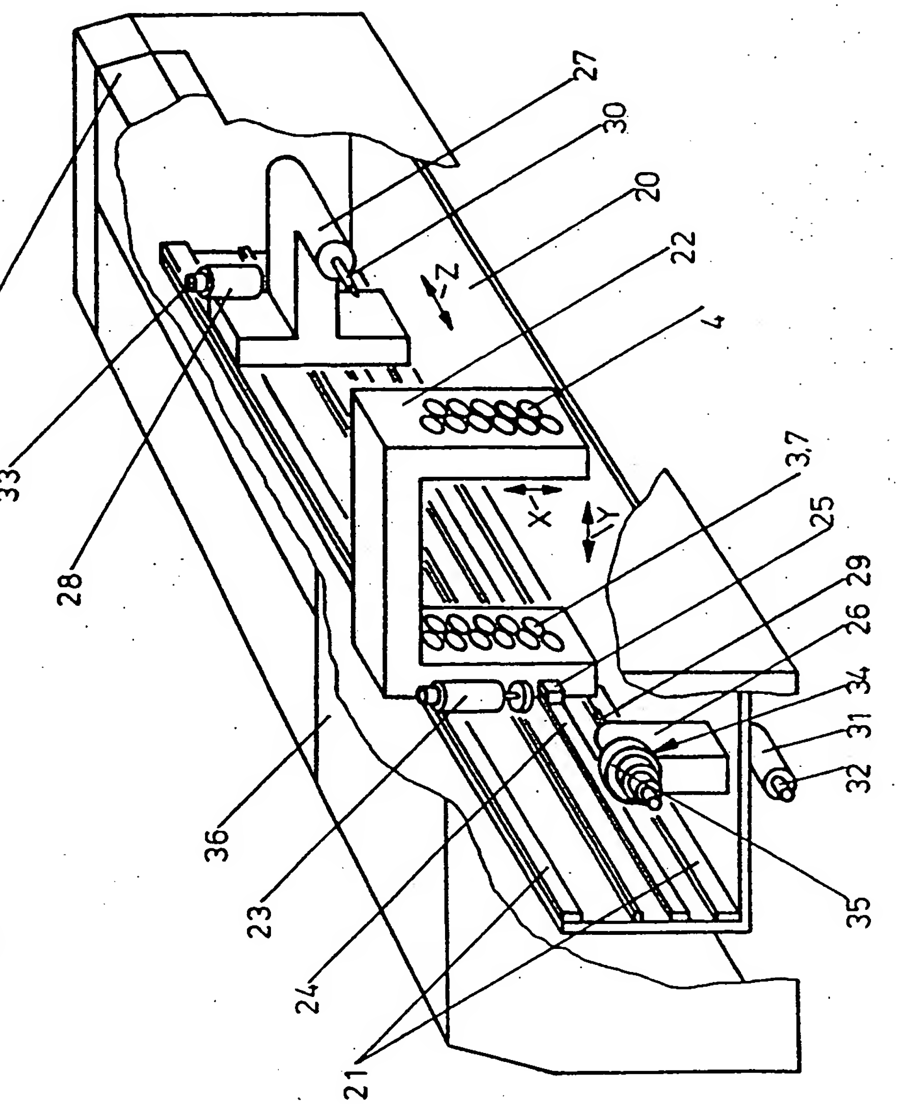


Fig.6

METHOD AND APPARATUS FOR THE OPTICAL ELECTRONIC MEASUREMENT OF A WORKPIECE

This is a continuation, of application Ser. No. 810,930, filed Dec. 18, 1985, now abandoned.

FIELD OF THE INVENTION

This invention relates to an apparatus and method for the optical-electronic measuring of machine parts or other objects.

BACKGROUND OF THE INVENTION

Prior art optical-electronic measuring methods for the testing or measuring of parts or workpieces, utilize the shadow produced by the workpiece, when the workpiece is illuminated with a beam of radiation. The shadow is detected by sensing apparatus which produces electrical signals that are interpreted for purposes of measurement. Thus, these prior art measuring methods use geometrical optics as opposed to wave optics.

The degree of measuring precision that can be achieved by these measuring methods often is not sufficient. In addition, when using such measuring methods, it is often required that precise distances be maintained between light source, workpiece and sensor. There may be an unfavorable effect as concerns measuring precision, if the distances cannot be maintained with the required precision during construction or assembly, or if the size of the workpiece or object to be measured is changed during the measuring process, for instance due to temperature changes or vibrations. In the prior art measuring methods, it is often necessary that the required precision be maintained even upon a displacement of the measuring instrument longitudinally relative to the workpiece to be measured. Another disadvantage is that to obtain a precise measurement the sensor must have a high capacity of resolution. It should be noted that many sensors which are available at the present time do not have a satisfactory resolution capacity. This problem may be solved in part when the electronic signals produced by the sensor are evaluated, which, however, detracts from the reliability of the measuring results.

German patent application DE-OS No. 2458807 discloses a method for measuring the distance between parallel lines in connection with the manufacture of semiconductor integrated circuits. The method of the German patent application uses diffraction patterns. Here the diffraction pattern is obtained from light reflected by the object measured. Because of the required reflection of the light by the object measured, application of this measuring method is very limited and can only be used in connection with devices such as semiconductor integrated circuits.

It is the object of the present invention to create a method and apparatus for the optical electronic measuring or testing of a workpiece or other objects wherein the disadvantages inherent in the known methods can be prevented. It is a further object of the invention to provide a measuring method and apparatus that has a measuring precision in the micron range and has multi-application purposes, such as the measuring of diameters and longitudinal distances as well as for testing or determining the contours of parts.

SUMMARY OF THE INVENTION

The present invention is an optical-electronic method and apparatus for measuring diameters of workpieces and other objects and for determining the contours of objects. The apparatus and method of the invention, despite being of simple construction as concerns the measuring optics, will afford an ample measuring range while keeping the measuring precision constant.

In the present invention an edge of a workpiece is illuminated with a beam of radiation to form an actual diffraction pattern. The actual diffraction pattern is converted into electronic signals by means of a sensor and correlated with a predetermined and possibly theoretically calculated diffraction pattern.

Thus, the present invention uses the diffraction patterns produced by a workpiece to measure the workpiece rather than using a geometrical optics technique, such as sensing the shadow produced by the workpiece. As a result, in the method and apparatus of the present invention, the position of the workpiece edge to be measured need not be exactly positioned relative to the sensor, as is required when a shadow-type geometrical optics technique is used. With the utilization of computerized image processing, the contour of the workpiece edge to be measured is determined by way of computer programs. Thereby, a contour can be determined with greater precision than a contour that is determined by way of geometrical imaging. Even the strong interference effects that are felt with the utilization of laser light do not have an adverse effect on the method of this invention; rather, they contribute to the exact determination of the edge contour or distance to be measured.

By using the apparatus of this invention, all requirements are fulfilled as concerns the testing of parts or workpieces in an automatic manufacturing process. These requirements are:

- contact-free measuring;
- short measuring times (a few seconds);
- a greater measuring range;
- a low degree of measuring uncertainty (a few micrometers);
- short evaluation times, so that the working tools can be adjusted without waste of time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a schematic representation of a measuring apparatus and method for measuring a workpiece, in accordance with an illustrative embodiment of the invention;

FIG. 2 shows a diffraction pattern which is produced when a workpiece is illuminated, in accordance with an illustrative embodiment of the present invention;

FIG. 3 shows the schematic arrangement of the sensors in relation to the workpiece to be measured, in accordance with an illustrative embodiment of the present invention;

FIG. 4 shows the diffraction images in a diameter-measuring process;

FIG. 5 shows a block diagram of a measuring apparatus in accordance with an illustrative embodiment of the present invention; and

FIG. 6 shows an embodiment of a measuring apparatus in accordance with an illustrative embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The measuring apparatus illustrated in FIG. 1 shows a workpiece or other object 1 to be measured or tested. The workpiece 1 has an edge 2 arranged between a light source 3 and a sensor 4. When illuminated with light, the edge 2 produces a diffraction image 8 which is converted into electrical signals by the sensor 4. The electrical signals 5 generated in sensor 4, corresponding to the diffraction image 8, are transferred to an evaluation device 6 which illustratively comprises one or more computers, in which the position and/or contour of edge 2 is calculated. Here, the coherent and monochromatic light source 3 is preferably a laser diode, whose radiation is widened by a lens system 7 and directed parallel. The lens system 7 is preferably achromatic. Any small aberrations resulting from the use of the achromatic lens system 7 can be removed to a considerable extent in the computer through correction programs.

For a rotationally symmetrical workpiece, such as the workpiece 1 shown in FIG. 2, it is often desirable to determine the contour of the workpiece edge along the Z-axis.

A surface sensor which provides a two-dimensional image, such as a CCD-matrix camera, may be used for this purpose. However, the resolution or the measuring range resulting therefrom would be insufficient. In the present invention, one or more line sensors 4, which can be displaced along the Z-axis (FIG. 3) during the measuring operation relative to the workpiece to be measured are used to measure the contour of the edge. Such a line sensor may have up to three times the measuring range of a surface sensor and typically comprises a sufficient quantity of diodes arranged linearly to separate the higher order diffraction maxima. The light sensitivity of the individual diodes of the line sensor 4 varies up to about 10%, whereby image evaluation can be made difficult and the measurement result can include errors. This, however, can be corrected beforehand, by determining certain parameters for each diode, inputting them into the computer, and compensating for such variations when the final evaluation is made by means of a fast technique, such as the "Pixel Correction".

The diffraction pattern 8 detected by the line sensor 4 as a result of illumination of edge 2 by light source 3 is shown in FIG. 2, wherein the light intensity of the diffraction image has been represented in the direction of the X-axis. The diffracted image 8 shows the maximum values 9 and minimum values 10 and also the intersection points 12, which intersect the mean light intensity line 11. The diffracted image 8, especially the maxima 9, the minima 10 and the intersection points 12 are evaluated, wherein these values and a diffracted image that has been theoretically calculated or obtained through simulation and then stored, serves as starting points for the calculation. In FIG. 2, the first and second intensity peaks along the X-axis are the zero and first order maxima of the diffraction pattern of FIG. 2, respectively. The theoretically obtained diffraction image is based on a theoretical position and contour of the object or workpiece to be measured. In the calculation, a correlation of the theoretical diffracted image and the measured diffracted image takes place. The theoretical diffraction image is calculated by known formulas, such as, for instance, the one given by M. Born, E. Wolf, in *Principles of Optics*, Pergamon Press, Oxford 1975, which is inputted in the computer's storage (memory). In FIG. 2, the theoretical position of edge 2 has been designated by the reference character 2*a*.

FIG. 3 shows an arrangement of linear sensors 4, which is used to enlarge the measuring range of the measuring apparatus illustrated in FIG. 6. Here several line sensors 4 are provided, arranged in two linear rows one after the other in such a way that there is a mutual overlapping 13 of sensor measuring ranges in the X-direction. Preferably, a light source 3 is attributed to each line sensor 4 of FIG. 3. In the example illustrated, seven line sensors 4 have been arranged, wherein the sensor 4*a* has a first measuring range, the two sensors 4*b* have a second measuring range, the two sensors 4*c* have a third measuring range and the two sensors 4*d* have a fourth measuring range. The two rows of linear sensors 4 are separated by a fixed distance 14 along the Z-axis. The maximum measuring range of each set of sensors 4*a*, 4*b*, 4*c*, 4*d*, in each case, is represented by the successively larger diameters of the step-shaped rotationally symmetrical part 1. For example, the diameter D1 may, for example, be measured using the two line sensors 4*b*, wherein the diffracted images 8*b* illustrated in FIG. 4 are produced, from which the actual diameter D1 is calculated.

FIG. 6 shows an embodiment of a measuring apparatus. A stand 20 is provided with guide rails 21 on which stand there is arranged a sled 22, displaceable along the Z-axis. On the U-shaped sled 22, there are arranged at oppositely disposed locations along the Y-axis, the line sensors 4, and the light sources 3 and associated lens systems 7.

The sled 22 is provided with an NC-controlled drive 23, wherein the exact location of the sled on the Z-axis is determined by means of a linear measuring stick 24 and a distance indicator 25. The receiving arrangement for the part or workpiece to be tested comprises a headstock 26 and a tailstock 27. The tailstock 27 is provided with a delivery drive 28 and an angle indicator 33. The workpiece is held between the tips 29, 30. Tip 29 of headstock 26 can be activated by means of a rotary drive 31 which is provided with an angle indicator 32 for indicating angular positions.

A reference body 34 is arranged coaxially to tip 29 on headstock 26. Reference body 34 comprises several cylindrical discs 35 that differ in diameter, wherein two different reference diameters have been attributed to each measuring range defined by the arrangement of the linear sensors 4*a*, 4*b*, 4*c*, 4*d* (FIG. 3). By means of reference body 34, it is possible to check the measuring system at the reference diameters and, if necessary, make adjustments. If desired, the reference body 34 may also be activated by the rotary drive 31, whereby measurements may be obtained at different angular positions. For example, when measurements are disturbed by dirt, new clean measuring spots can be set.

The whole arrangement is provided with a covering hood 36 for protection against external influences, such as stray light, dirt, etc., wherein parts or workpieces to be measured are passed in and out through an opening provided with a door 37. Within the covering, it will be convenient to create an over-pressure, for instance by means of a blower, so that the penetration of dirt and dust can be prevented as much as possible.

FIG. 5 shows a block diagram for the afore-described measuring apparatus. Sensors 4 and the light sources 3 are activated by means of an analog-digital converter 41.

and are connected by means of a measuring-range control 40 to an interface computer 42. The computer 42 is also connected to the drive 23 and the distance indicator 25 by way of control device 44. In addition, the computer 42 is connected to the rotational drive 31 and the angle indicator 32. An analysis computer 43 for performing the above-described correlations and calculations is connected to interface computer 42. The computer 43 is provided with an actuating connection for the delivery drive 28 of the tailstock 27 and its angle indicator 33. Furthermore, there are provided on the computer 43, the analysis, indicating and servicing mechanisms 45, 46 and 47.

In order to obtain automatic operation in connection with a processing machine 49 and a loading device 48, the analysis computer 43 is connected with controls of the processing machine 49 and loading device 48.

The measuring apparatus described is primarily intended for the testing and measuring of rotationally symmetrical parts, wherein their diameters, lengths, and contours can be precisely measured. In addition, chamferings, threadings and perforations can be checked. Through the use of the rotary drive, there may also be controlled, measured, and/or tested the roundness and rotational trajectory of a workpiece. It may also be possible to measure or test the longitudinal trajectory of a workpiece or other object. With the measuring method and apparatus of the present invention, it will also be possible to measure the roughness of a surface.

A distance measurement between two edges of a workpiece having different locations along the X-axis can be performed, in accordance with the present invention, without displacing the workpiece or measuring apparatus along the Z-axis (as described in connection with FIGS. 3 and 4). To measure the distance between the two edges at different positions along the Z-axis, a displacement of the workpiece relative to the light source/sensor arrangement along the Z-axis takes place during the measuring process. Thus, a sequence of measurements are made at different axial locations along the workpiece piece to be measured through use of the diffraction patterns formed by illuminating the edges of the workpiece.

The afore-described measuring method, illustrated in FIGS. 1 and 2, can also be used for non-rotationally symmetrical workpieces or other parts, where, in this case, the apparatus described in connection with FIG. 6 must be formed to receive the corresponding parts.

If dirtied parts are to be cleaned before the measuring process, for instance, by immersion in a fluid and/or by the action of a centrifuge, then any remaining residue can be compensated in the measuring process.

By loading stored programs into the interface and/or analysis computers, further parameters can be included to increase measuring precision. Here it will be possible to make the following corrections based on values measured or ascertained:

- temperature workpiece/environment;
- the diffracted image produced by the existing optics vis-a-vis the theoretical image;
- distinctly identifying and/or locating the diffraction maxima and minima allows a conclusion on the type of surface of the parts or objects to be measured, and allows for a determination of the size of the corrections.

Finally, the above described embodiments of the invention are intended to be illustrative only. Numerous, alternative embodiments may be devised by those skilled in the art without departing from the spirit and scope of the following claims.

We claim:

1. An optical electronic method for measuring or testing a workpiece comprising the steps:
   (a) illuminating at least one edge of the workpiece with a coherent monochromatic light source to generate an actual diffraction pattern;
   (b) directly sensing the actual diffraction pattern including a zero order intensity maximum with at least one line of sensors to convert said actual diffraction pattern into electrical signals to produce a first set of data representative of the intensity of light of said actual diffraction pattern as a function of spatial position;
   (c) maintaining a second set of data representative of the intensity of light of a predetermined diffraction pattern as a function of spatial position; and
   (d) correlating said first and second sets of data to compare said actual and said predetermined diffraction patterns.

2. The method of claim 1 wherein said workpiece is rotationally symmetric.

3. A method as claimed in claim 1, wherein said first set of data includes maximum and minimum values of the light intensity of the actual diffraction pattern, and intersection points of the actual diffraction pattern with the average light intensity.

4. A method according to claim 1, wherein through the generation of diffraction images at the upper and the lower edge of said workpiece the measuring distance between the edges is ascertained.

5. A method according to claim 1 in which the workpiece is placed in rotation during or between measurings.

6. An apparatus for optical-electronically measuring or testing an object, said apparatus comprising
   a coherent, monochromatic light source for illuminating at least one edge of the object,
   at least one line of sensors for directly detecting the actual diffraction pattern including a zero order intensity maximum produced as a result of illuminating said edge of said object, and for converting said actual diffraction pattern to electrical signals to produce a first set of data representative of the intensity of light of said actual diffraction pattern as a function of spatial position,
   means for maintaining a second set of data representative of the intensity of light of a predetermined diffraction pattern as a function of spatial position; and
   means for correlating said first and second sets of data to compare said actual and said predetermined diffraction patterns.

7. An apparatus according to claim 6, wherein said apparatus includes several lines of sensors that are arranged in first and second rows in such a way that there is mutual overlapping of the measurement ranges of sensors in said first row and sensors in said second row, each of said sensors in said first and second rows having a coherent monochromatic light source associated therewith.

8. An apparatus according to claim 6, wherein the light source comprises a laser diode and a lens system for the generation of parallel rays.

9. An apparatus according to claim 7, wherein the light sources and the sensors are arranged on a sled displaceable along guide means parallel to the longitudi-

nal axis of the workpiece to be measured so that said workpiece can be measured at various locations along its longitudinal axis.

10. An apparatus according to claim 7, wherein the said apparatus includes a receiving mechanism for said workpiece comprising a tailstock including a delivery drive, and a headstock including a rotary drive, said drives being electronically actuated.

11. An apparatus according to claim 9, wherein a reference body is arranged along the displacement path of the sled.

12. An apparatus according to claim 11, wherein the reference body comprises several cylindrical discs with different diameters.

13. An apparatus according to claim 9, wherein the apparatus is provided with a covering hood for protection against external influences, and wherein within the covering an overpressure is created.

14. An apparatus for measuring a workpiece having a longitudinal axis, comprising:

a source of illumination for providing a beam of coherent, monochromatic light which propagates along a path perpendicular to the longitudinal axis

of said workpiece, for illuminating at least one edge of said workpiece,

lines of sensor means arranged along said path for directly detecting the actual diffraction pattern including a zero order intensity maximum produced by the diffraction of aid light by said edge, and for converting said actual diffraction pattern into electrical signals to produce a set of data representative of the intensity of light of said actual diffraction pattern as a function of spatial position,

means for moving said path and said workpiece longitudinally relative to one another so that an actual diffraction pattern can be detected and a corresponding set of data produced at various longitudinal locations along said workpiece,

means for maintaining one or more sets of data representative of the intensity of light as a function of position of one or more predetermined diffraction patterns; and

means for correlating each set of data representative of an actual diffraction pattern with a set of data representative of a predetermined diffraction pattern to compare each actual diffraction pattern with a predetermined diffraction pattern.

* * * * *

EXHIBIT C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Werner Blohm, Harald Sikora; and Adrian Beining

Continuation of

Serial No.: 09/211,614 Group Art Unit: 2877

Filed: December 15, 1998 Examiner: Richard A. Rosenberger

Title: METHOD OF MEASURING THE DIAMETER OF AN ELONGATED ARTICLE OF A CIRCULAR CROSS SECTION

Assistant Commissioner for Patents
Washington, D.C. 20231

DECLARATION OF DR. WERNER BLOHM

1. I am Dr. Werner Blohm, and am employed by Sikora International. I am of the age of majority and am otherwise competent to make this declaration.

2. I am listed as an inventor in this application. Attached is a brochure that shows "Inline 2000 Laser 2010XY/LASER 2025XY" XY diameter gauge heads which correspond to what is disclosed and claimed in the application. This brochure was prepared by and is circulated by the assignee of this application, Sikora Industrieelektronik GmbH.

3. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true. These statements are made with the knowledge that willful false statements are punishable by fine or imprisonment under §1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

December 03, 2001
Date

W. Blohm
Werner Blohm

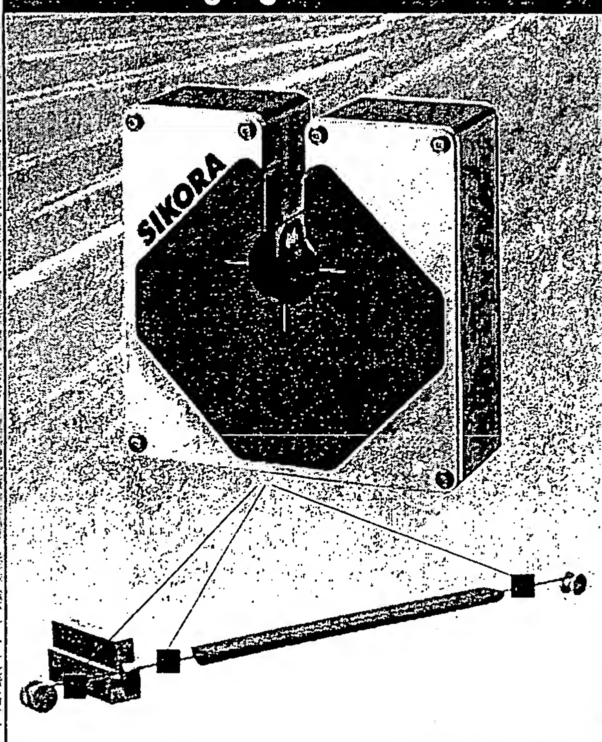
INLINE 2000

Technology To Perfection

Measuring technique for cable production lines

- LAN cables
- coaxial cables
- RF and telephone cables
- automotive wires
- installation / building wires
- optical fibers

LASER 2010XY / LASER 2025XY
XY-diameter gauge heads



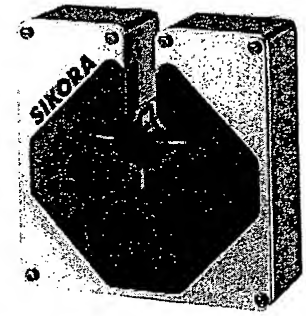
SIKORA

INLINE 2000

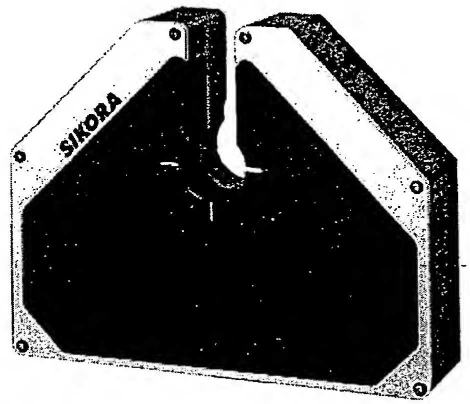
Technology To Perfection

A completely new generation of measuring and testing equipment, laid out especially for production lines for LAN, coaxial, RF and telephone cables as well as optical fibers

- **diameter measurement**
- **capacitance measurement**
- **eccentricity / diameter measurement**
- **lump / neckdown detection**
- **spark testing**



LASER 2010XY



LASER 2025XY

LASER 2010XY / LASER 2025XY • XY-diameter gauge heads

LASER 2000XY stands for measuring technology of the latest standard, which facilitates with the permanently increasing demands of the wire and cable industry for quality and productivity.

Highest precision, reliability and functionality are the remarkable assets of these extremely small gauge heads, for a product diameter range from 0,1 to 25 mm, which can be easily integrated in every type of production line.

Most interesting is the detection of periodical diameter variations (FFT) and the prediction of the structural return loss (SRL) which is directly integrated in the gauge head and accessible with every PC or notebook via a RS 232 diagnostic interface.

The **LASER 2010XY/LASER 2025XY** offer various interfaces for adapting the gauge heads to a process control computer or to the processor based display and control system **REMOTE 2000** resp. the **ECOCONTROL 2000**.

Typical features

- state of the art CCD-measuring technique combined with pulse driven laser diodes
- extremely short aperture time of 0,8 µsec.
- data processing is completely within the measuring head
- trend, statistics, calculation of standard deviation
- FFT-analysis with a resolution in the nanometer range
- SRL-prediction (option)
- RS 485 / Profibus / analog interfaces
- RS 232 for PC-, modem-, internet-diagnosis
- extremely small dimensions because of SMD-technique
- almost unlimited lifetime

Technical data	**LASER 2010XY**	**LASER 2025XY**
product diameter	0,1 to 10 mm	0,2 to 25 mm
accuracy	+/– 0,5 µm*	+/– 1,0 µm*
repeatability**	0,1 µm	0,2 µm
resolution	0,1 µm	0,1 µm
exposure time	0,8 µsec	1,0 µsec
measuring rate	500 / sec	500 / sec
dimensions	140 x 140 x 54 mm	250 x 200 x 68 mm
power supply	100 - 245 V AC ± 10 %, 10 VA	

* + 0,01 % of the measured value
** ± 3 σ, 1 sec

subject to change without notice

ISO 9001 SIKORA QUALITY

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